NASA-CR-200672

Final Report — (for period 6/4/90-8/10/95) NAG3-1181 Hollow Cathode Particle Diagnostics

Professor Roy B. Torbert
Institute for the Study of Earth Oceans and Space
University of New Hampshire
Durham, New Hampshire 03824

11 March, 1996

The Experimental Space Physics group of the University of New Hampshire has completed its efforts supporting the SEDS/PMG mission. The SEDS/PMG experiment was conducted successfully on a Delta GPS launch from ETR on 28 June 1993. It carried a conducting tether between a "near end" and a "far end" package. Both the near and far end packages carried a hollow cathode plasma contactor, to enhance the connection to the ambient environment. UNH provided a set of particle detectors, for investigation of the payload potential and the particle populations existing around the payload.

The particle detectors included an electron detector and an ion detector. The ion detector could differentiate between oxygen and xenon masses, the two species expected near the SEDS/PMG payload. Both detectors were based on the "top-hat" electrostatic analyzer. Two electron look directions, two xenon look directions, and one oxygen look direction were telemetered, giving five particle data channels in all.

All five particle channels performed nominally until about 12000 seconds flight time (approximately two whole orbits of the spacecraft). UNH has worked with members of the SEDS/PMG team to display and interpret these data. The main result of the SEDS/PMG mission is that hollow cathodes do indeed provide a very low impedance contact to the ionosphere by enhancing electron collection. The particle detector signatures show that the payload potential can be controlled actively using voltages applied to one end of the conducting tether.

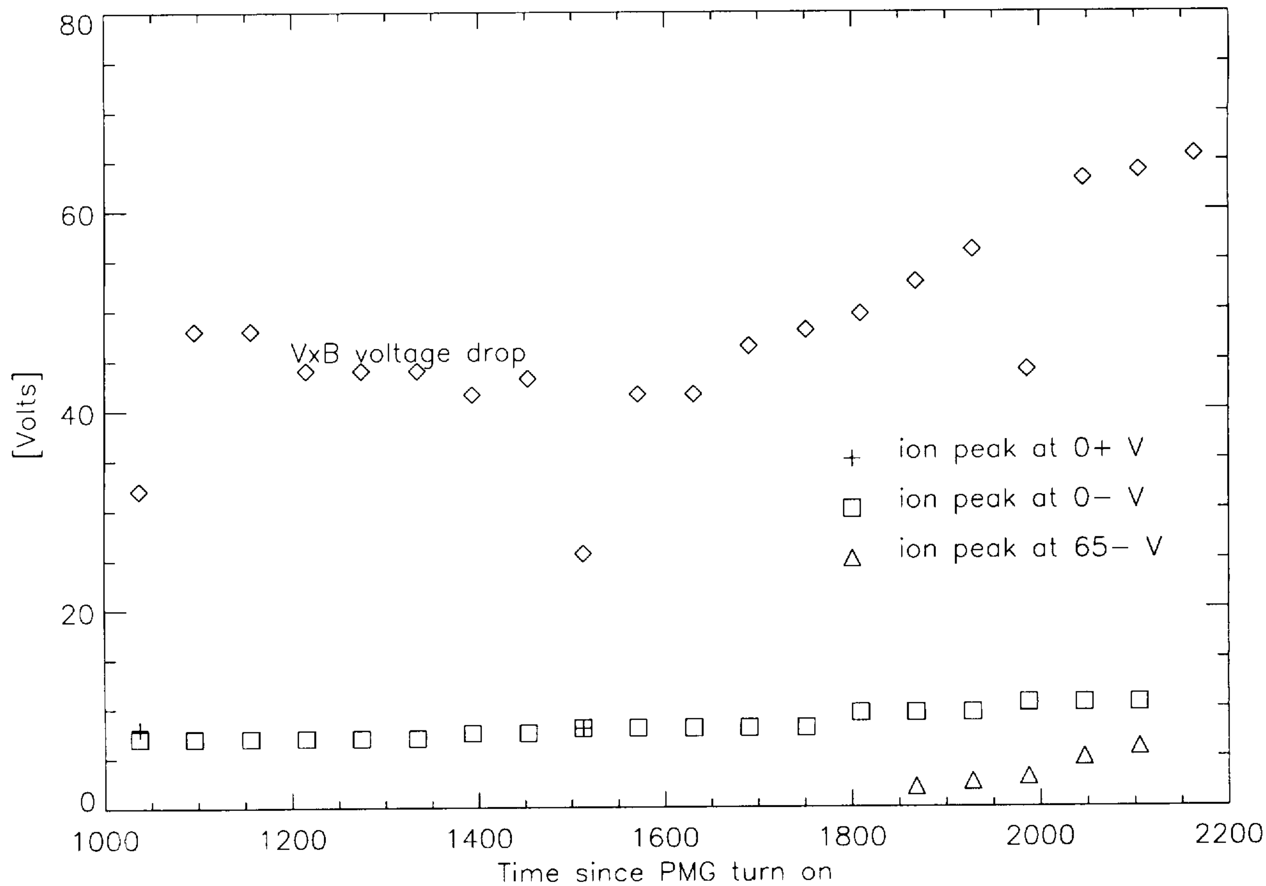
The results of the UNH particle analysis were presented to the scientific community in an AGU presentation. [K. A. Lynch, R. B. Torbert, J. Ketel, D. C. Ferguson, and J. E. McCoy, *Particle Measurements of Actively Controlled Spacecraft Potential on the SEDS/PMG Tether Package*, 1994 Fall AGU meeting.]

The attached figure shows the main result of this analysis: the energy of the measured ions is a function of the external $\mathbf{v} \times \mathbf{B}$ electric field, and the applied voltage on the tether. When the external field is significantly larger than the applied voltage between the near and far end package, the near end package sits at seven volts negative, and the far end package must therefore sit significantly positive. This can be seen in the ion data: the square points in the data plot show the peak ion energy when the applied voltage to the tether is 0 V; the peak ion energy is near 7 eV. The near end package is thus seen to be at a potential of -7V with respect to the local plasma ground.

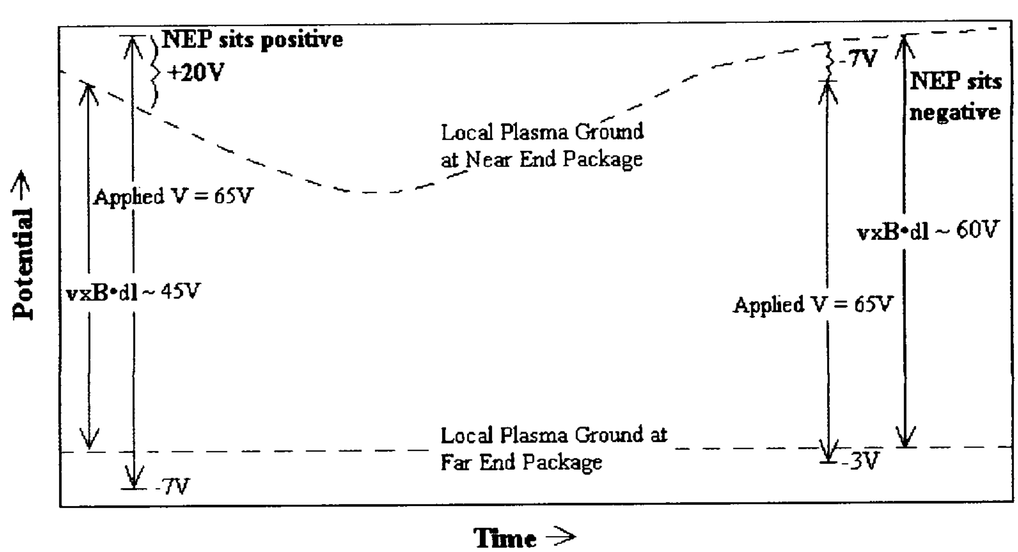
When the external field is less than the applied voltage, the near end package sits significantly positive and the far end package sits at -7V. This is illustrated in the lower left portion of the figure. Also, the ion data shows that when the external field increases to a value close to the applied voltage (lower right portion of figure), the near end package moves from positive, towards its maximum negative position of -7V. This can be seen in the ion data as well: triangular points from T+1800 onwards indicate the change of the payload potential to small negative values as the external field value increases with time.

The underlying physics behind this is that (a) it is easier for the package to sit positive than negative, and (b) the package likes to sit at -7V. Thus in general, one package sits at -7V, and the other floats to whatever positive (or 0 to -6V negative) voltage is required to make the applied voltage be equal to the external electric field dotted with the tether direction. This result shows that the spacecraft potential can be actively controlled by applied voltages working in tandem with the conducting tether and the hollow cathodes.

Figure 1: Top panel: Peak ion energies throughout the flight, for different values of applied tether voltage. The external $\mathbf{v} \times \mathbf{B} \cdot d\mathbf{l}$ electric field is also plotted for comparison. Bottom panel: Illustration of the various possible combinations of applied voltage, external field, and package potentials.



80
60
40
20
0
[Volts]
VxB voltage drop
ion peak at 0+ V
ion peak at 0− V
ion peak at 65− V
1000
1200
1400
1600
1800
2000
2200
Time since PMG turn on



NEP sits positive
+20V
-7V
NEP sits negative
Local Plasma Ground
at Near End Package
Applied V = 65V
vxB•dl ~ 60V
Potential
vxB•dl ~ 45V
Applied V = 65V
Local Plasma Ground at
Far End Package
-3V
-7V
Time